Report as of FY2007 for 2007PA73B: "Improved quantification of stream-aquifer interactions for tracking nitrate transport along a river continuum: implementation of a cost-effective distributed-temperature sensing technology"

Publications

Project 2007PA73B has resulted in no reported publications as of FY2007.

Report Follows

PRINCIPAL FINDINGS AND SIGNIFICANCE

This project provided seed funding to start a long-term data collection of stream bottom temperature in the FD-36 watershed with the goals of quantifying the heterogeneity and seasonality of groundwater discharge to the first-order stream. In June of 2007, we deployed a fiber-optic distributed temperature sensor (FO-DTS) along 500 m of the stream within FD-36, and have collected continuous temperature data with resolution of 1 meter, every 5 minutes, to 0.1°C. The start of the line is near "Flume 1" in this stream, and the end of the line extends a bit beyond the "Flume 4." The cable was destroyed in a storm in March 2008, but I have recently purchased a replacement cable which will be deployed later this summer. This project is a proof-of-concept study to explore how temperature can be used to help constrain baseflow contributions to streams in an agricultural setting. Results of this work will provide information required to quantify the and predict nutrient loading in space and time.

Because of the high temporal and spatial resolution of FO-DTS, there is a tremendous amount of data collected with these methods. Example data are shown below. We can capture the temporal dynamics of the stream warming and cooling throughout the data along the stream reach (Figure 1), and note that the timing and magnitude of the warming varies daily (Figure 2, 3). We have devoted considerable time in FY07 to determine how best to parse and visualize these data and thereby discriminate processes of interest. For example, we have looked at Fourier transform as a way to quantify the frequency content of data and identify changes in power spectrum spatially along the stream. To quantify patterns in this data set, we took the temperature data for each entire month at a given position, subtracted the average temperature at that location, and then computed the Fourier Transform. Figure 4 is a representative power spectra for components at the fundamental frequency up to frequencies three days. The majority of the amplitude lies in the component with a daily frequency, which is not surprising, as without annual data, seasonal trends will be impossible to ascertain. Additionally the magnitude of the power spectra decreases upstream, indicating that variations are less apparent near Flume 4 than Flume 1.

Stream discharge and meteorological data, including air temperature and solar radiation, were compared to the stream temperature data. Cross-correlations between these data sets were calculated, and indicate that the air temperature leads the stream temperature by approximately three hours. The solar radiation tends to lead the stream temperature by about five hours. As described in the Fourier data, the air temperature and solar radiation data show a larger correlation with the stream temperature near Flume 1 as compared to Flume 4. We are currently exploring the correlation between stream discharge and temperature. We have demonstrated that there is certainly a correlation between air temperature and stream temperature, and expect to see changes in temperature correlating with gaining and losing pieces of the stream as based on the flume data. Ongoing work aims to (1) apply the wavelet and cross-wavelet transform to further characterize the time series and correlations between them; and (2) investigate relationships between nitrate concentration and stream thermal behavior.

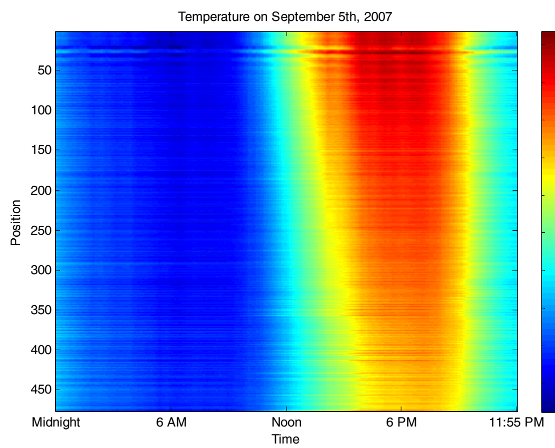

Figure 1. Temperature in °C in the stream on Sept 5, 2007. The x-axis is time during the day, and the y-axis indicates the position in m along the stream from Flume 1, going upstream.

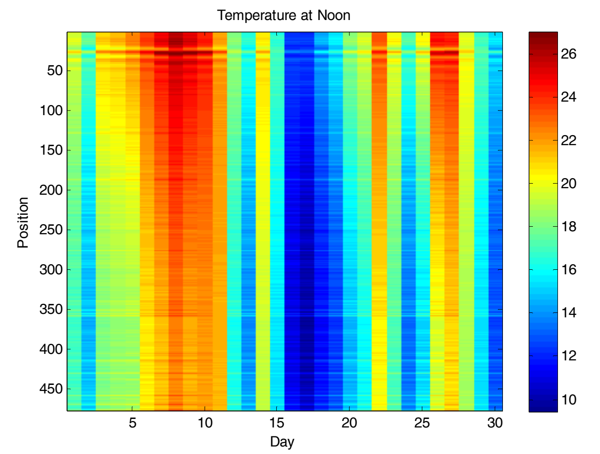

Figure 2. Temperature in °C in the stream at noon through the month of September, 2007. The x-axis is day of the month, and the y-axis indicates the position in m along the stream from Flume 1, going upstream.

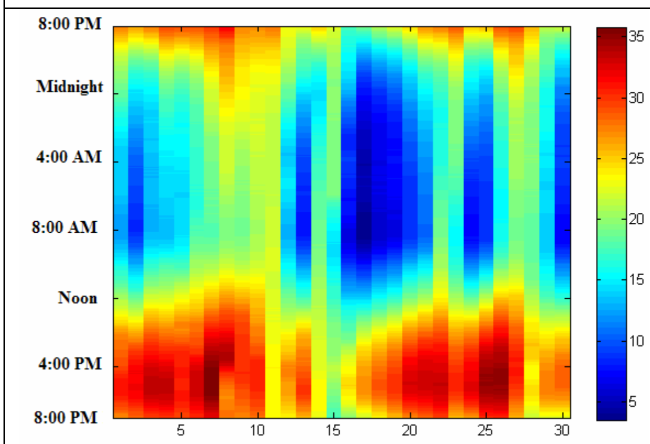

Figure 3. Temperature in °C in the stream 88 m from Flume 1 for the month of September, 2007. The x-axis is day of the month, and the y-axis indicates the time of day.

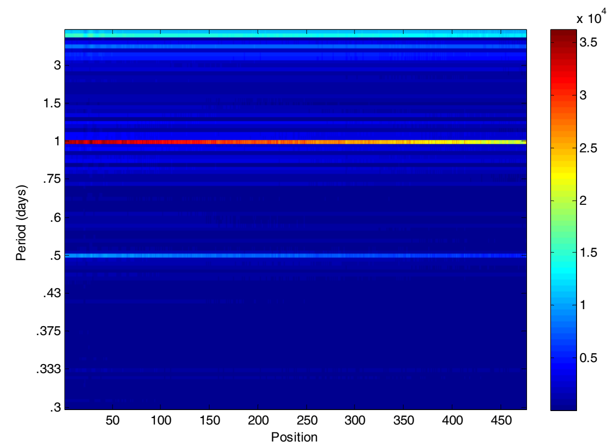

Figure 4. Fourier Transform of September temperature data. The x-axis is position in m from Flume 1, going upstream. The y-axis is the Fourier period in 1/days. The maximum amplitude occurs for 1-day cycles, and the amplitude is lower with distance from Flume 1.

STUDENTS SUPPORTED (name, major, degree)

Nicholas Rubert, Physics, Undergraduate Researcher
Ted Donovan, Geosciences, Undergraduate Thesis Student
Kristin Jurinko, Geosciences, Undergraduate Thesis Student
Brian Hamming, Geosciences, PhD student (left on medical leave just after project start, however)

PRESENTATIONS AND OTHER INFORMATION TRANSFER ACTIVITIES

Invited Talks

1. Ohio State University, School of Earth Sciences, January 2008.
2. Ecole Polytechnique Fédérale de Lausanne/Université de Lausanne Institut de Géophysique,

Switzerland, May 2007.

3. Forschungszentrum Jülich GmbH, Institute of Chemistry and Dynamics of the Geosphere, Germany, June 2007.
4. University of Wisconsin-Madison, Water Resources Seminar, February 2007 (unable to present due to flight cancellations out of State College).
5. CUAHSI-supported training course, “Fiber-Optic Distributed Temperature Sensing for Ecological Characterization,” September 2007
6. USGS training course “Use of Heat as a Tracer for Surface/Ground-Water Interactions, October, 2007

ADDITIONAL FUNDING ACQUIRED USING USGS GRANT AS SEED MONEY (source, amount, starting and ending dates, title)

USGS Grant used as seed for a recent NSF-EAR proposal submission to Hydrologic Sciences:
Loheide, S.P. and Singha, K. “Collaborative Research: Quantifying and manipulating stream-aquifer interactions at a stream restoration site”. $321,954. Start/end dates: 9/1/08 - 8/31/11.